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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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Ogden, Utah

February 1961

BIOLOGICAL EVALUATION OF SPRUCE BUDWORM INFESTATIONS IN THE NORTHERN ROCKY MOUNTAIN REGION IN 1960

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(NOT FOR PUBLICATION)

Prepared by the
Forest Insect Laboratory
Missoula, Montana

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INTRODUCTION

Spruce budworm (Choristoneura fumiferana (Clem.)), is an important insect pest in the northern Rocky Mountain region. Infestations are persistent in large areas of forested land, especially in Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco) forests in southwestern Montana. Budworm outbreaks have been recorded in the region since 1921, but epidemic infestations undoubtedly occurred periodically prior to that date.

The greatest damage from budworm occurs in nearly pure stands of Douglas-fir on dry, marginal sites; less damage occurs on better sites even in the midst of serious infestations, and the least damage is in stands of intermixed tree species.

The current spruce budworm outbreak dates from about 1947. By 1958 the infestation was general throughout most of the Douglas-fir type in southwestern Montana, and several outbreaks had developed in Idaho (figure 1). The current outbreak had infested 4,674,912 net acres[1/] of timber by 1958 (table 1).

During the course of the current outbreak, some infestations developed and later subsided without treatment. Control efforts, the aerial application of insecticide, have reduced other infestations and were undoubtedly the factor in eliminating some of them. In other instances reinfestation has quickly occurred in the more persistent outbreak areas.

1/ This is the latest revised acreage figure available, compiled from various sources by the Division of State and Private Forestry, Forest Service, Region 1. It represents a refinement from the gross acreages used in previous reports because openings in the forest and non-host types have been largely eliminated.

During the past two years the Forest Insect Laboratory has made annual biological evaluations of the spruce budworm infestation on a regionwide basis. Evaluations are based upon both budworm population and damage records. Budworm has several life stages during each season which presented a problem as to which stage would provide the best sample of the population. In 1959 three life stages were sampled: overwintering larvae, moths, and eggmmasses. Overwintering larvae proved to be the least useful of these stages and were eliminated from the sampling in 1960. In 1960 the sampling was confined to moths and egg masses to record the population level and defoliation as a measure of the damage from current larval feeding.

The objective of this study was to determine the association between budworm populations of the year and defoliation damage of the subsequent year. By establishing a correlation between population and subsequent damage it was hoped to develop a method of predicting future defoliation. This report presents the results of a regionwide biological evaluation of spruce budworm in 1960 based on an analysis of data collected during the season and compared with comparable data recorded in 1959. By projecting related factors into the future an attempt is made to predict the degree of defoliation in 1961.

METHODS

Twenty-five permanent sample plots were established in Montana in 1959 to sample budworm activity. These plots were distributed to cover a wide range of infestation conditions (figure 1). Each plot consists of five or more intermediate Douglas-fir trees in an even-canopied stand. Annual samples of population and damage are taken from the same trees. From this sampling design comparative data are obtained from year to year.

Each sample plot was visited twice during 1960. During the period July 26 to August 5, estimates of current defoliation were made and at the same time population was recorded. Defoliation was estimated by viewing each of the plot trees at close range through 9 X 35 power binoculars. Separate estimates of defoliation were made for the upper, middle, and lower crown. These ocular estimates were periodically checked by cutting typical limbs from the tree and inspecting the new-growth shoots to determine the actual percentage of defoliation caused by larval feeding. Later, the estimates by crown thirds were weighted by the multipliers 1, 3, and 5 for upper, middle, and lower crowns, respectively, to compensate for the greater amount of foliage in the middle and lower crown. The product was then divided by 9, the sum of the multipliers, to get the average defoliation for each tree.

Budworm moth population was obtained by clipping four 15-inch twigs from each plot tree at mid-crown. The sampling was done during the late pupal stage. Pupae were removed from the twigs and placed in collection jars with a bit of foliage. A separate jar was used for each sample twig where pupae were found. In some instances moths had emerged prior to the sampling. Where this had occurred the vacated pupal cases were collected and later examined to determine if a moth had successfully emerged or if the pupa had harbored a parasite. Collection jars were brought in to the Laboratory where the moths emerged from pupae. A record was thus obtained of successful moth emergence and parasitism in the pupal stage.

In early September the final visit to the plots was made to collect foliage samples from which budworm egg masses were recorded. Limbs were cut from opposite sides of each plot tree at mid-crown. All the foliated twigs were clipped from the limbs and placed in plastic bags. Ten samples were collected from each of the 25 plots--a total of 250 samples. The sacked foliage was brought to Missoula, Montana and placed in cold storage at about 38°F.

After the collection of foliage had been completed in mid-September, four women were hired to examine the foliage and remove needles bearing egg masses. As needed, the foliage was taken from storage and evenly spread on a canvas and the area covered by the foliage was measured. Samples varied somewhat but averaged about 1,700 square inches. A total of 441,800 square inches of foliage was inspected and yielded 1,601 new egg masses.

CURRENT STATUS OF INFESTATIONS

From general observation, budworm infestations in Montana, appeared to decrease in severity in a few areas in 1960. The decreases in defoliation were rather spotty but noticeable. In Idaho, two areas once heavily defoliated are now no longer considered to be epidemically infested. They are the Riggins Unit on the Nezperce National Forest and the Powell Unit on the Lolo National Forest, with a combined total of 190,080 acres. These two units were sprayed with DDT for budworm control in 1955 and 1956 respectively. The infestations declined since that time. Budworm infestation near Craig Mountain south of Lewiston, Idaho continues but is much less evident than in 1959. Except for the improvements described above, the area infested by budworm in 1960 was much the same as it was in 1958 and 1959.

Data recorded in 1960 indicate that a downward trend may be taking place in the budworm infestation in Montana:

	1959	1960
Percent defoliation	38	34
Moths per 15-inch twig	1/ 1.11	1/ 0.95
Egg masses per 1,000 square inches of foliage	2/ 10.36	2/ 3.63

1/ These data are from 22 plots. Plot 23 was sprayed in 1960 and was therefore eliminated from both 1959 and 1960 columns.

2/ Data from 24 plots.

Defoliation.--In using defoliation as a measurement of budworm activity, it might be well to weigh both shoot growth and defoliation, because with variations in shoot growth from year to year percentage of defoliation alone loses meaning. This is illustrated as follows:

	Defoliation (percent)	New foliage growth (inches)	Growth destroyed (inches)	Net length of new growth (inches)
1959	38	.81	.31	.50
1960	34	.60	.21	.39

While the percent of defoliation may have decreased slightly in 1960, the amount of new foliage eaten by larvae was about 30 percent less. This would indicate a greater decrease in budworm activity than percentage of defoliation alone (table 2).

In terms of actual damage to the tree, the defoliation in 1960 may have been worse than the somewhat heavier defoliation in 1959 because there was less new growth in 1960. Net length of new growth shoots in 1960 was 22 percent less than in 1959 as a result of budworm defoliation and the reduction in natural needle growth.

Moth population.--The small decrease in moth population indicated in table 3 is not significant. Data on moth population were from 22 sample plots where comparable data were available in 1959. Data were collected from all 25 plots in 1960, however, and for the first time a record of parasitism in the pupal stage was obtained. These data are presented in table 4. Because two additional plots were included, the average of moths per 15-inch twig is slightly lower than in table 3.

Parasitism varied greatly from plot to plot and the average of 20 percent is higher than ordinarily recorded from life history study plots in Montana. An additional 3 percent of the pupae failed to produce moths from causes unknown--perhaps from a diseased condition or from handling.

We have no basis for evaluating the effectiveness of parasitism of budworm in the pupal stage. Certainly it is an important factor.

Egg population.--A marked decrease in budworm egg masses occurred in 1960. The decrease occurred in nearly all plots and appears to be highly significant (table 5). In 1959 the ratio of egg masses per 1,000 square inches of foliage to moths per 15-inch twig was 9.3 to 1; in 1960 the ratio was 3.8 to 1.

Parasitism in the egg stage was difficult to appraise because some egg masses showed evidence of parasitism in only a few of the eggs while nearly all eggs were affected in other masses. In 1951, 3.8 percent of the egg masses were parasitized; in 1960 only 1 percent were parasitized. Egg mass parasitism was sporadic in 1959, it occurred in 11 out of 24 plots and in 1960 in 4 of 24 plots.

We have no basis from which to evaluate the effects of egg parasitism.

INFESTATION TREND

The objectives of biological evaluations are to depict the current status of infestations and to estimate the trend they are apt to take. Forecasting the future trend of an infestation is difficult because so much often depends upon imponderable factors such as weather and biological relationships between the insect pest and various predators and disease. However, by determining past relationships between budworm population and subsequent defoliation and by projecting these findings into the future we hope to estimate future damage from current population abundance.

Data obtained during the past two seasons indicate a close correlation between budworm moths and defoliation and between egg masses and defoliation as follows:

	Moths per 15-inch twig	Egg masses per 1,000 sq. in. of foliage		Defoliation (percent)
1959	1.11	10.24		34 (1960)
1960	.95	3.63	est.	20.6(1961)

The relationship between moths in 1959 and defoliation in 1960 is shown in the regression in figure 2. As it is presented in the above tabulation, 1.11 moths per 15-inch twig in 1959 resulted in 34 percent defoliation in 1960. If this relationship held for the period 1960-1961 about the same amount of defoliation could be expected in 1961 as occurred in 1960. But it is obvious that the moths in 1960 did not lay as many egg masses as the moths did in 1959. Therefore, the 1960-1961 relationship between moths and defoliation will probably not be the same as it was in the 1959-1960 period.

If a prediction is made from the current budworm population in the egg stage, the relationship between egg masses in 1959 and defoliation in 1960 will be the base of the prediction. This relationship is presented in the regression in figure 3. Such a prediction would indicate that a decrease in defoliation will occur in 1961. Based on 3.63 egg masses per twig, the defoliation in 1961 is estimated as 20.6 percent.

Egg mass data are probably a better measurement of budworm populataion for predicting the infestation's trend than are moths. Egg mass data has the advantage of being one development stage, or interval, nearer to the larval stage that will cause defoliation. An unknown factor, moth flight mortality, is past and the flight period may be a very critical one.

These are the best predictions that can be made from the data available. Further tests of this method of prediction must be made before its reliability can be established.

Table 1.--Acreage infested by spruce budworm during the period 1947-1960 and notes on control treatment applied

National Forest	Unit	Acres	Control treatment (aerial spraying, DDT)
Beaverhead	Pioneer	105,761	Partially, 1956 Remainder, 1957
	Horse Prairie	31,704	Partially, 1956 Remainder, 1957
	Lima	88,910	All, 1957
	Ruby	34,144	All, 1956
	Blacktail	27,716	Partially, 1956 Remainder, 1957
	Madison	82,101	All, 1957
	Centennial	16,716	No treatment
Beaverhead-Deerlodge	Fleecer Mtn.	79,480	All, 1957
	Tobacco Root	84,825	All, 1957
Beaverhead-Gallatin	East Madison	45,100	No treatment
	Hebgen	72,731	All, 1957
Gallatin	Gallatin River	165,888	Partially, 1960
	Hyalite	45,475	No treatment
	Bridger Mtns.	241,030	No treatment
	Crazy Mtns.	196,640	No treatment
	Trail Creek	166,279	No treatment
	Pine Creek	82,209	Partially, 1960
	Mill-Gardiner	196,048	Partially, 1955 Remainder, 1960
	Boulder River	46,679	No treatment
Deerlodge	West Continental	25,483	No treatment
	South Continental	130,291	Partially, 1957
	Basin Creek	78,722	Partially, 1953
	Flint Creek	129,056	No treatment
Helena	Clancy	21,772	Partially, 1953
	Nevada Creek	120,597	No treatment
	Marysville	163,096	Partially, 1953
	Lincoln	184,051	No treatment
	Big Belt Mtns.	153,635	All, 1956
	Deep Creek	124,412	Partially, 1958

Table 1 (continued).--Acreage infested by spruce budworm during the period 1947-1960 and notes on control treatment applied

National Forest	Unit	Acres	Control treatment (aerial spraying, DDT)
Helena-Deerlodge	Elkhorn-Crow Cr.	132,855	Partially, 1953 All, 1956
Lewis and Clark	White Sulphur	253,912	All, 1956 Partially, 1957
	Judith	113,110	Partially, 1957
Lolo	Rock Creek	85,473	No treatment
	Powell	1/ 119,371	Partially, 1956
Helena-Lewis and Clark	Smith River	171,597	No treatment
Bitterroot	Bitterroot	471,621	Partially, 1952, 1955, and 1959
Nezperce	Riggins	1/ 70,709	Partially, 1953 All, 1955
Yellowstone Park	Yellowstone	71,678	Partially, 1955 Remainder, 1957
Other ownerships	Craig Mtn.	89,481	No treatment
	Blackfoot	154,554	No treatment
	Total	4,484,832	

1/ These two areas are no longer epidemically infested and are not included in the total.

Table 2.--Percentage of spruce budworm defoliation and foliage growth

Plot	1959 Defoliation percent	1959 Growth inches	1960 Defoliation percent	1960 Growth inches
1	8.6	1.11	0.0	0.86
2	44.3	0.79	45.8	0.56
3	42.3	0.81	64.4	0.53
4	43.7	0.91	52.3	0.75
5	62.2	1.04	55.0	0.83
6	35.2	0.94	19.7	0.70
7	13.5	0.70	2.0	0.53
8	11.3	0.71	2.0	0.62
9	34.7	0.93	13.1	0.79
10	0.3	1.17	2.0	0.82
11	54.5	1.12	42.3	0.77
12	1.8	0.72	0.0	0.44
13	72.7	0.80	34.5	0.67
14	53.3	0.51	53.9	0.45
15	50.1	0.92	52.2	0.54
16	4.0	0.64	5.7	0.49
17	36.8	0.83	63.1	0.51
18	84.4	0.64	72.5	0.41
19	90.0	0.77	100.0	0.43
20	67.5	0.58	19.6	0.47
21	12.9	0.79	60.3	0.56
22	30.2	0.71	38.9	0.53
24	11.8	0.81	5.8	0.65
25	55.0	0.50	17.5	0.59
Total	921.1	19.45	822.6	14.50
Aver.	38.4 $\pm$ 7.4%	0.81 $\pm$ 4.4%	34.3 $\pm$ 3.11%	0.60 $\pm$ 6.35%

Table 3.--Spruce budworm moths per 15-inch twig from 22 plots

Plot	1959	1960	Plot	1959	1960
1	0.00	0.00	13	2.65	1.15
3	3.20	3.85	14	2.70	1.65
4	0.40	0.86	15	1.15	0.45
5	1.40	0.35	16	0.50	0.05
6	0.10	0.05	17	1.85	2.00
7	0.05	0.00	18	2.70	1.55
8	0.25	0.00	19	3.50	4.75
9	0.60	0.15	20	0.65	0.05
10	0.00	0.00	21	0.65	1.29
11	0.90	0.85	24	0.15	0.10
12	0.00	0.00	25	1.15	1.75
			Average	1.11 $\pm$ 21.3%	0.95 $\pm$ 28.7%

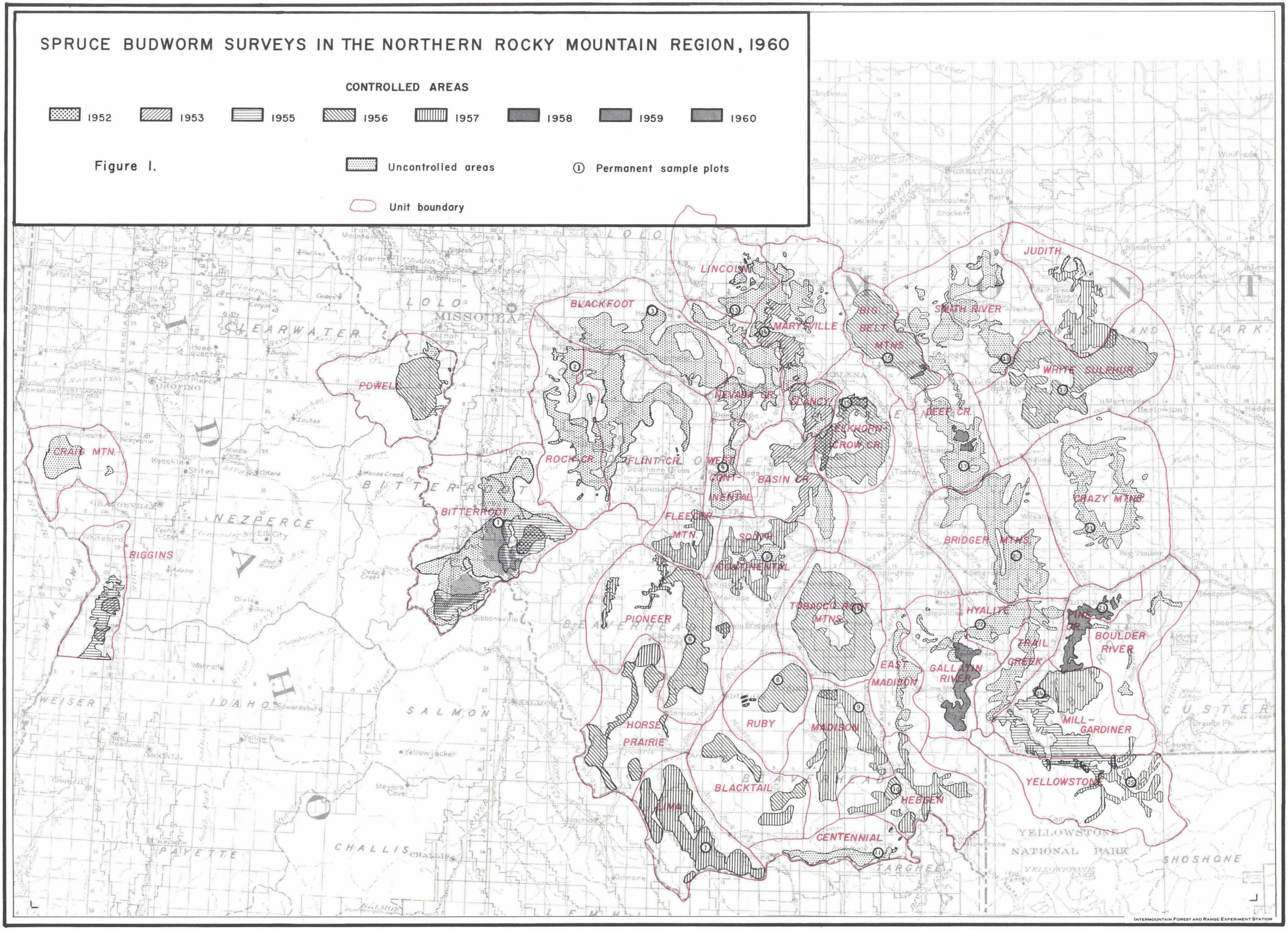
Table 4.--Pupal cases, percent of parasitism, and moths per 15-inch twig from 25 plots in 1960

Plot	Pupal cases	Percent parasitized	Moths emerged	Plot	Pupal cases	Percent parasitized	Moths emerged
1	.05	100	0.00	14	2.10	16 + 5*	1.65
2	1.18	6	1.11	15	0.75	40	0.45
3	4.15	7	3.85	16	0.05	0	0.05
4	0.86	0	0.86	17	2.33	9 + 5*	2.00
5	0.55	36	0.35	18	1.90	18	1.55
6	0.10	50	0.05	19	6.85	22 + 9*	4.75
7	0.00	0	0.00	20	0.05	0	0.05
8	0.00	0	0.00	21	1.68	23	1.29
9	0.15	0	0.15	22	2.20	41 + 2*	1.25
10	0.00	0	0.00	23	0.05	100	0.00 (spray. '60)
11	0.90	6	0.85	24	0.15	33	0.10
12	0.00	0	0.00	25	2.30	24	1.75
13	1.95	33 + 8*	1.15	Ave.			
				Ave.	1.21	20 + 3*	0.93

* Percent mortality from unknown cause

Table 5.--Spruce budworm egg masses per thousand square inches of foliage in 1959 and 1960

	Egg masses			Egg masses	
Plot	1959	1960	Plot	1959	1960
1	0.00	0.40	13	21.98	6.17
2	10.80	9.87	14	35.18	7.05
3	16.56	10.57	15	10.62	6.14
4	11.66	2.26	16	1.10	0.25
5	7.78	2.53	17	15.66	6.01
6	0.32	0.14	18	21.32	10.97
7	0.24	0.07	19	36.58	9.00
8	3.26	0.99	20	10.36	0.41
9	18.46	1.37	1	3.92	4.11
10	0.18	0.09	22	3.56	0.76
11	12.64	6.18	24	2.32	0.39
12	0.00	0.00	25	4.08	1.46
			Ave.	10.36 $\pm$ 20.8%	3.63 $\pm$ 21.0%


SPRUCE BUDWORM SURVEYS IN THE NORTHERN ROCKY MOUNTAIN REGION, 1960
CONTROLLED AREAS
1952
1953
1955
1956
1957
1958
1959
1960
Figure 1.
Uncontrolled areas
① Permanent sample plots
Unit boundary
JUDITH
LINCOLN
BLACKFOOT
MARYSVILLE
BIG BELT MTNS
SMITH RIVER
WHITE SULPHUR
POWELL
NEVADA CR.
CLANCY
DEEP CR.
ELKHORN-CROW CR.
CRAIG MTN.
ROCK CR.
FLINT CR.
WEST CONTINENTAL
BASIN CR.
CRAZY MTNS.
BITTERROOT
FLEECER MTN.
SOUTH CONTINENTAL
BRIDGER MTNS.
RIGGINS
PIONEER
TOBACCO ROOT MTNS.
HYALITE
PINE CR.
BOULDER RIVER
TRAIL CREEK
EAST MADISON
GALLATIN RIVER
RUBY
MADISON
HORSE PRAIRIE
MILL-GARDINER
YELLOWSTONE
BLACKTAIL
HEBGEN
LIMA
CENTENNIAL
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION

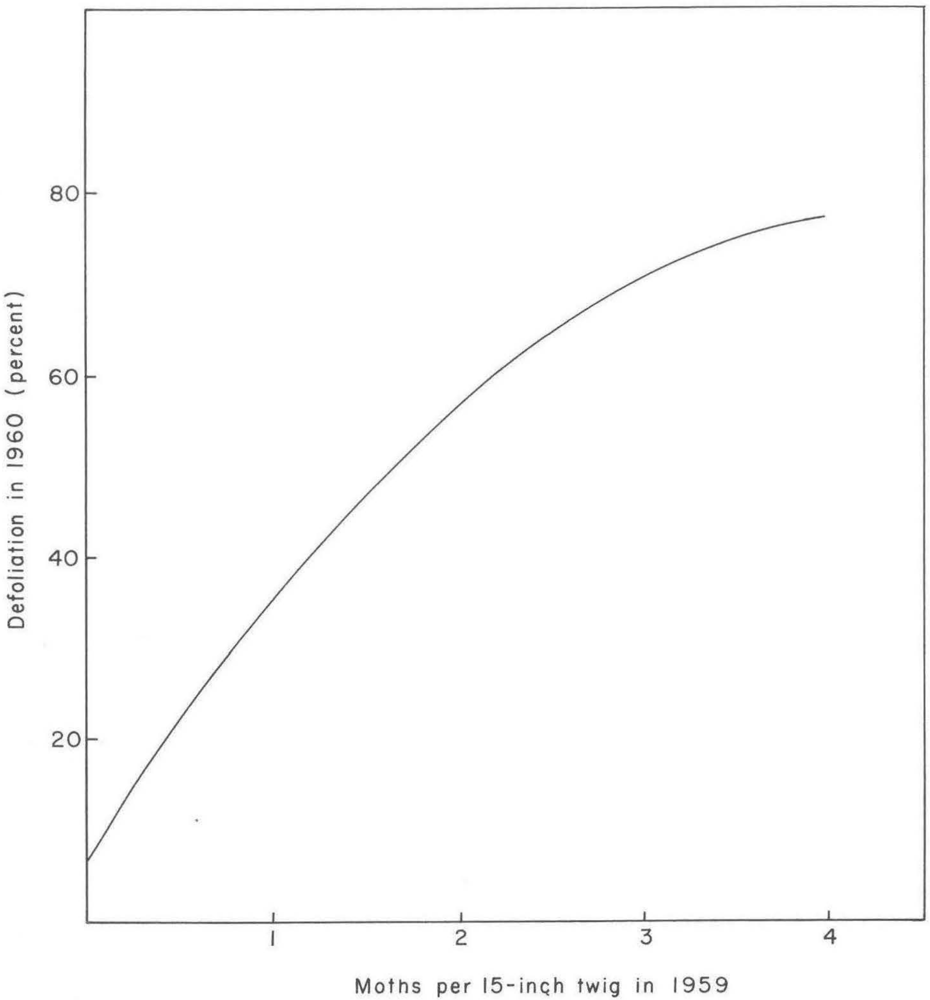


Figure 2.--Relationship of moths to defoliation

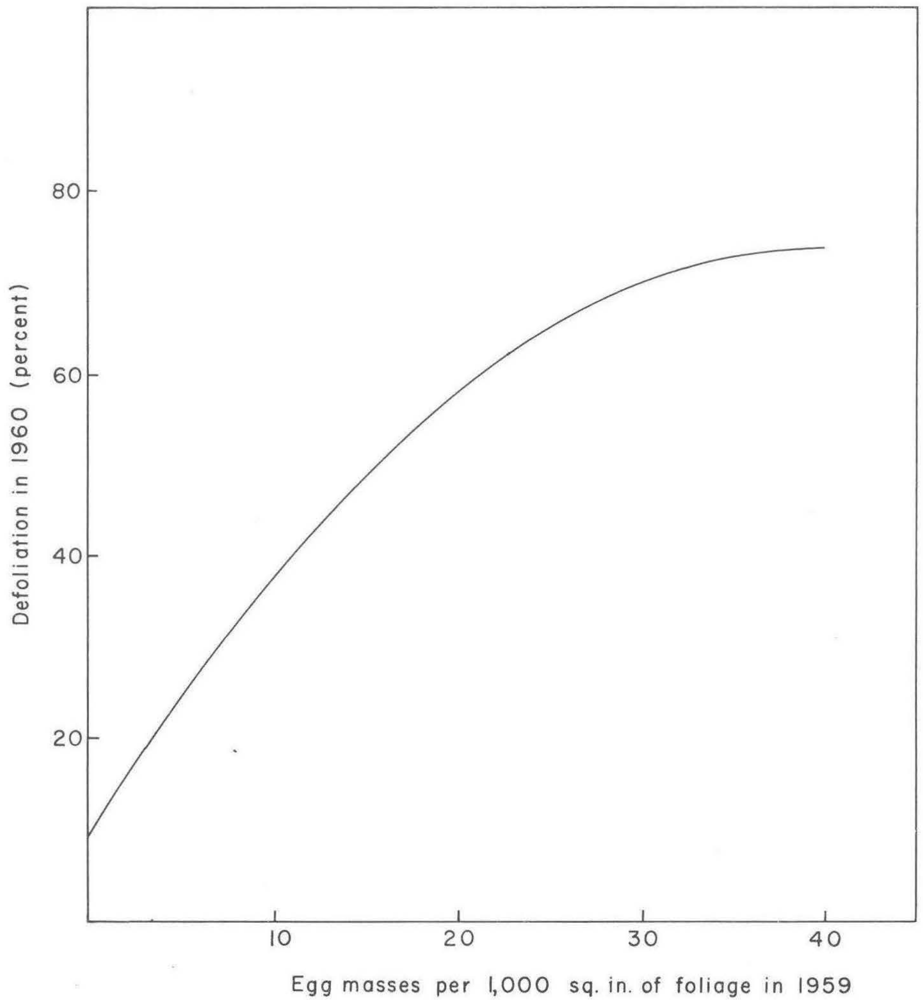


Figure 3.-- Relationship of egg masses to defoliation